Appl. No.: 10/659,938
Amdt. dated 02/07/2005
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Amendments to the Claims:

1. (currently amended) A method of friction stir welding a workpiece, the method comprising:

urging a friction stir welding pin against the workpiece;

rotating the friction stir welding pin; and

adjusting a rotational speed of the friction stir welding pin cyclically between a minimum speed and a maximum speed with an average speed that is greater than zero and thereby friction stir welding the workpiece,

wherein said adjusting step comprises cyclically adjusting the rotational speed of the pin at a frequency of variation between about 0.1 Hz and 100 Hz.

2. (previously presented) A method according to Claim 1 wherein said adjusting step comprises cyclically adjusting the rotational speed of the pin between first and second predetermined speeds.

3. (previously presented) A method according to Claim 1 wherein said adjusting step comprises cyclically adjusting the rotational speed of the pin between first and second predetermined speeds, the first speed being at least about 100 RPM and the second speed being greater than the first speed.

4. (previously presented) A method according to Claim 1 wherein said adjusting step comprises cyclically adjusting the rotational speed of the pin between first and second predetermined speeds, the first speed being less than 99% of an average rotational speed of the pin and the second speed being greater than 101% of the average rotational speed of the pin.

5. (cancelled)

6. (previously presented) A method according to Claim 1 wherein said adjusting step comprises cyclically adjusting the rotational speed of the pin according to a sinusoidal variation in speed.

7. (currently amended) A method according to Claim 1 wherein said adjusting step comprises cyclically ~~reversing the rotational direction of the pin~~ adjusting the rotational speed of the pin to the minimum speed, the minimum speed being greater than zero and in the same direction as the maximum speed, such that the pin rotates in a single direction.

8. (previously presented) A method according to Claim 1 wherein said adjusting step comprises providing a varying electric current to an actuator for rotating the pin.

9. (previously presented) A method according to Claim 1 further comprising heating the workpiece to a preheat temperature before said urging step.

10. (previously presented) A method according to Claim 9 wherein said heating step comprises energizing an induction heater.

11. (previously presented) A method according to Claim 9 wherein said heating step comprises heating the workpiece by at least 50° F to a temperature that is less than a plasticizing temperature of the workpiece.

12. (previously presented) A method according to Claim 1 further comprising providing the workpiece, the workpiece comprising at least one of the group consisting of aluminum, aluminum alloys, titanium, titanium alloys, and steel.

13. (previously presented) A method according to Claim 1 wherein said rotating step comprises rotating a friction stir welding pin having first and second independently rotatable portions.

14. (previously presented) A method according to Claim 13 wherein said adjusting step comprises adjusting a rotational speed of each portion of the friction stir welding pin cyclically such that the first and second portions rotate at different speeds during at least a portion of said adjusting step.

15. (previously presented) A method according to Claim 1 further comprising providing the pin, the pin having at least two portions, the portions defining dissimilar diameters.

16. (currently amended) A method of friction stir welding a workpiece, the method comprising:

urging a friction stir welding pin against the workpiece;

rotating the friction stir welding pin; and

adjusting a rotational speed of the friction stir welding pin between a minimum speed and a maximum speed with an average speed that is greater than zero in accordance with a predetermined schedule and thereby friction stir welding the workpiece,

wherein said adjusting step comprises adjusting the rotational speed of the pin at a frequency of variation between about 0.1 Hz and 100 Hz.

17. (previously presented) A method according to Claim 16 wherein said adjusting step comprises adjusting the rotational speed of the pin between first and second predetermined speeds, the first speed being at least about 100 RPM and the second speed being greater than the first speed.

18. (previously presented) A method according to Claim 16 wherein said adjusting step comprises adjusting the rotational speed of the pin between first and second predetermined speeds, the first speed being less than 99% of an average rotational speed of the pin and the second speed being greater than 101% of the average rotational speed of the pin.

19. (cancelled)

20. (currently amended) A method according to Claim 16 wherein said adjusting step comprises ~~reversing the rotational direction of the pin~~ adjusting the rotational speed of the pin to the minimum speed, the minimum speed being greater than zero and in the same direction as the maximum speed, such that the pin rotates in a single direction.

21. (previously presented) A method according to Claim 16 wherein said adjusting step comprises providing a varying electric current to an actuator for rotating the pin.

22. (previously presented) A method according to Claim 16 further comprising heating the workpiece to a preheat temperature before said urging step.

23. (previously presented) A method according to Claim 22 wherein said heating step comprises energizing an induction heater.

24. (previously presented) A method according to Claim 22 wherein said heating step comprises heating the workpiece by at least 50° F to a temperature that is less than a plasticizing temperature of the workpiece.

25. (previously presented) A method according to Claim 16 further comprising providing the workpiece, the workpiece comprising at least one of the group consisting of aluminum, aluminum alloys, titanium, titanium alloys, and steel.

26. (previously presented) A method according to Claim 16 wherein said rotating step comprises rotating a friction stir welding pin having first and second independently rotatable portions.

27. (previously presented) A method according to Claim 26 wherein said adjusting step comprises adjusting a rotational speed of each portion of the friction stir welding pin in accordance with a predetermined schedule such that the first and second portions rotate at different speeds during at least a portion of said adjusting step.

28. (previously presented) A method according to Claim 16 further comprising providing the pin, the pin having at least two portions, the portions defining dissimilar diameters.

29. (currently amended) A friction stir welding apparatus comprising:

a rotatable pin structured to be urged against a workpiece to friction stir weld the workpiece;

an actuator configured to rotate the pin; and

a controller configured to adjust the actuator and thereby adjust a rotational speed of the pin according to a predetermined schedule,

wherein the controller is configured to cyclically adjust the actuator and thereby adjust the rotational speed of the pin at a frequency of <u>variation</u> between about 0.1 Hz and 100 Hz <u>between a minimum speed and a maximum speed with an average speed that is greater than zero</u>.

30. (previously presented) A welding apparatus according to Claim 29 wherein the controller is configured to cyclically adjust the actuator and thereby adjust the rotational speed between first and second predetermined speeds.

31. (previously presented) A welding apparatus according to Claim 29 wherein the controller is configured to cyclically adjust the actuator and thereby adjust the rotational speed between first and second predetermined speeds, the first speed being at least about 100 RPM and the second speed being greater than the first speed.

32. (previously presented) A welding apparatus according to Claim 29 wherein the controller is configured to cyclically adjust the actuator and thereby adjust the rotational speed of the pin between first and second predetermined speeds, the first speed being less than 99% of an average rotational speed of the pin and the second speed being greater than 101% of the average rotational speed of the pin.

33. (cancelled)

34. (currently amended) A welding apparatus according to Claim 29 wherein the controller is configured to cyclically adjust the actuator and thereby adjust the rotational speed of the pin sinusoidally.

35. (currently amended) A welding apparatus according to Claim 29 wherein the controller is configured to cyclically ~~reverse the rotational direction of the pin~~ adjust the rotational speed of the pin to the minimum speed, the minimum speed being greater than zero and in the same direction as the maximum speed, and thereby rotate the pin in a single direction.

36. (previously presented) A welding apparatus according to Claim 29 wherein the controller is configured to adjust an electric current provided to the actuator.

37. (previously presented) A welding apparatus according to Claim 29 further comprising a heater configured to heat the workpiece.

38. (previously presented) A welding apparatus according to Claim 37 wherein the heater is an induction heater.

39. (previously presented) A welding apparatus according to Claim 29 wherein the pin includes first and second portions, the portions being independently rotatable.

40. (previously presented) A welding apparatus according to Claim 39 wherein the pin includes first and second actuators for independently rotating the first and second portions of the pin, respectively.

41. (previously presented) A welding apparatus according to Claim 29 wherein the pin defines at least two portions, the two portions defining dissimilar diameters.